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ANNUAL REPORT TO: Dr. Steven Ramberg, Ocean Engineering Division, ONR

PROJECT TITLE: Research on bluff-body vortex wakes.
N00014-90-J-1589

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PROJECT ABSTRACT

LONG-TERM GOALS:

1. Fundamental understanding of the near-wake dynamics of vortex shedding bluff bodies, including the interplay between body motion; vortex creation and motion, and force history.

2. Development of new techniques to study bluff body flows computationally and experimentally and to exploit the synergism that comes from such an approach.

3. Continue development of an experiment on wake interference, using splitter plates of various lengths and *solidities* (solidity 1 is a solid plate and solidity 0 is the case of a free wake). This should give some new insights into the near-wake mechanics and the role of absolute cf convective instability.

SIGNIFICANT ACCOMPLISHMENTS IN FY90, AND APPROACHES USED:

1. A computational technique, based on two dimensional wortex methods, was developed to study unsteady flows past flat plates with large-scale separation and in the Re range of 10^4. The technique captures the actual scale of the vortex sheets as they emerge from the edges of the plate. This scale defines the flow Reynolds number. The accuracy of the method was verified by

   a. comparison with tow-tank measurements of time-dependent drag during a ramp start

   b. comparison with theoretical results of Pullin on the time-dependent vortex circulation after an impulsive start and

   c. comparison with experiment of the growth of the recirculation bubble before flow asymmetry begins.

2. *Nonoscillating Case*

   a. Computed and experimental drag histories compare well during ramp start up.

   b. Drag falls off, while flow remains symmetric. Disagreement between computed and experimental values significant after dimensionless time of about 5.

c. Asymmetry established at times (> 10) which depend on perturbations.

d. Surprisingly large dimensionless time (> 50) to reach steady vortex shedding state.

e. Steady-state mean drag about 2.0 in tow-tank, comparable to wind-tunnel values, but about 3.5 in computation. Base-pressure distributions quantitatively and qualitatively different.

f. Differences thought to be due to development of three dimensionality in the experiment. Real, two dimensional mean-flow dynamics are affected by 3-d turbulence; computed flow is purely two dimensional. In addition, real flow may be affected by end effects.

3. *Oscillating Cases (plate oscillating in its place)*

   a. Earlier establishment of asymmetry, by time 5, with larger drag overshoots.

   b. Even longer time to reach steady state; possibly dependent on reduced frequency and low frequency (beat) modulation.

   c. Less difference between computed and experimental mean drag, possibly due to increased effect of forced two dimensional motion in latter case.

4. *Wake-interference Effects.* An experiment has been initiated in our 20×20" wind tunnel. Behind circular cylinders or the bluff cylinders spanning the tunnel, solid splitter plates or screens (open splitter plates) can be installed. Preliminary measurements show the expected effect of the screen splitter, ie reduction of drag but not so much as for a solid splitter. Variations with Reynolds number observed.

OBJECTIVES IN FY91:

1. Computational: Extend the two dimensional vortex method to represent more realistically and accurately the flow near the separation edges. Implement some code simplification to allow numerical computation of more flows and longer (dimensionless) times.

2. Experimental: Study development and effects of intrinsic three dimensionality in the tow-tank flows, also possible effects of and conditions (at free surface and at bottom).

3. Combined: Explore in more detail the vortex-shedding resonant range of forced frequencies in the plate-oscillating case. Examine near wake vortex dynamics and the long time to reach steady state.

4. Wake interference experiments: Develop the experiments which have been initiated. Cylinder pressure distributions, wake hot-wire measurements and flow visualization planned.

WORK TO BE CONTINUED:

1. Development of computational methods with extension to three-dimensional vorticity

2. Role of three dimensionality in mean-two-dimensional near wakes.

3. Wake interference and relevance to absolute cf convective instability.

OFFICE OF NAVAL RESEARCH
PUBLICATIONS/PATENTS/PRESENTATIONS/HONORS REPORT
1 Oct 89 through 30 Sep 90

R&T Number:

Contract/Grant Number: N00014-90-J-1589

Contract/Grant Title: Research on bluff-body vortex wakes

Principal Investigator: Anatol Roshko, Anthony Leonard

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a. Number of Papers Submitted to Refereed Journal but not yet published: 0

b. Number of Papers Published in Refereed Journals: 0
(list attached)

c. Number of Books or Chapters Submitted but not yet Published: 0

d. Number of Books or Chapters Published: 0 (list attached)

e. Number of Printed Technical Reports & Non-Refereed Papers: 2
(list attached)

f. Number of Patents Filed: 0

g. Number of Patents Granted: 0 (list attached)

h. Number of Invited Presentations at Workshops or Prof. Society Meetings: 7

i. Number of Presentations at Workshops or Prof. Society Meetings: 1

j. Honors/Awards/Prizes for Contract/Grant Employees: 2
(list attached, this might include Scientific Soc. Awards/ Offices, Promotions/Faculty Awards/Offices, etc.)

k. Total number of Graduate Students and Post-Docs Supported at least 25% this year on this contract/grant:

Grad Students 4 and Post-Docs 0 including
Grad Student Female 0 and Post-Docs Female 0
Grad Student Minority 0 and Post-Doc Minority 0

Minorities include Blacks, Aleuts, AmIndians, Hispanics, etc.
NB: Asians are not considered an under-represented or minority group in science and engineering.

Enclosure (3)

PUBLICATIONS FROM ONR SPONSORED WORK - FY 90
ANATOL ROSHKO, ANTHONY LEONARD
DECEMBER 1990

89-IC Chua, K., Lisoski, D., Leonard, A. and Roshko, A., (1989) A numerical and experimental investigation of separated flow past an oscillating flat plate. Proceedings of the International Symposium on Nonsteady Fluid Dynamics, meeting of ASME, Toronto, Canada 3-7 June, 1990.

89-R Chua, K., Vortex Simulation of Separated Flows in Two and Three Dimensions. Ph. D. thesis, California Institute of Technology, 1990.

LIST OF HONORS/AWARDS/PRIZES FOR CONTRACT/GRANT EMPLOYEES:

Anthony Leonard - Caltech - Visiting Scientist to the John von Neumann Supercomputer Center, Rutgers/Princeton, New Jersey, October-November, 1989.

Anatol Roshko - Caltech - Recipient of the L.S.G. Kovasznay Distinguished Lectureship, University of Houston, 1990.